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Effect of exercise and suspensory on scrotal surface temperature in the stallion

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Effect of exercise and suspensory on scrotal surface temperature in the stallion

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Abstract

In this study, the effect of exercise (treadmill, riding) on scrotal surface temperature (SST) in the stallion with and without suspensory was evaluated. Experiments were carried out between September and November 2004 using 12 Franches-Montagnes stallions from the National Stud in Avenches (Switzerland). Each stallion performed a standardized incremental treadmill and a ridden test with and without suspensory. The intensity of exercise was monitored by heart rate and blood lactate concentration. For SST measurements, special thermistors were developed and affixed to the most ventral part of the scrotum over each testis. SST was recorded telemetrically at 1 min intervals. Our results show that type of exercise (treadmill/ridden) and suspensory (with/without) significantly influenced SST. The mean SST level was higher during treadmill (32.2 ± 0.02°C) than during ridden exercise (30.4 ± 0.03°C) and mean SST differences between stallions with and without suspensory were smaller in treadmill (0.4°C) than in ridden (2°C) exercise. These findings clearly demonstrate that ambient air flow, which was higher during ridden exercise, is important and effective in SST regulation. In order to prevent possible thermal damage to spermatogenic cells we recommend removing the suspensory immediately after exercise.

1. Introduction

Maintenance of testes at a temperature lower than body temperature is critical for normal spermatogenesis. When testicular temperature is elevated as a result of inflammation, fever or high ambient temperature, metabolism increases at a greater rate than blood flow and hence the testes become hypoxic. Testicular thermoregulation in most mammals is accomplished by relaxation of scrotal muscles, scrotal sweat glands, heat loss from the scrotal surface and the arterio-venous countercurrent heat exchange mechanism at the pampiniform plexus [1-3]. An experimentally induced increase in scrotal and testicular temperature is known to affect spermatogenesis and has been investigated in bulls [4-8], rams [9-13], boars [14-16], rabbits [17-19] and stallions [20,21].

In the horse, intense exercise has been shown to dramatically increase core body temperature above 41°C [22,23]. Impairment of testicular heat exchange may be caused by scrotal suspensories, the use of which has become popular in show-jumping and trotting stallions to prevent excessive testicular movement during training and competition. As yet, the influence of increased body temperature and the wearing of a scrotal suspensory on SST has never been shown. The aim of this study was to investigate the effect of intense treadmill and ridden exercise on SST in the stallion with and without suspensory.

2. Material and methods

2.1. Animals

Experiments were performed between September and November 2004 using 12 Franches-Montagnes stallions aged between 7 and 14 years from the National Stud in Avenches (Switzerland). All animals were kept in individual boxes bedded with straw. They were in good training condition and were fed hay, oats and pellets supplemented with minerals. Water was available ad libitum.

2.2. Experimental design

To increase core body temperature, each stallion was exercised on a treadmill and by riding at various intensities during six consecutive periods of 18 min each. Exercise was performed with and without suspensory (Stallion Support, Wahlsten OY, Lahti, Finland). A picture of the suspensory in place is shown in Fig. 1.

Fig. 1. Stallion wearing the netlike suspensory.

Treadmill exercise

Before starting the treadmill experiment all stallions were habituated to exercise on the high speed treadmill (Mustang 2200, Kagra AG, Fahrwangen, Switzerland). The exercise program shown in detail in Table 1 consisted of a warm up period (I), two periods (II and III) of increasing workload and three recovery periods (walking IV and V, resting VI). The indoor ambient temperature and humidity were measured by a wireless 433 MHz weather station (TFA, Reichholzheim, Germany) and ranged between 12.1°C and 23.2°C at a relative humidity between 56% and 74%. A ventilator (Isler Bioengineering AG, Zürich, Switzerland) placed 4 meters in front of the treadmill directed an airflow (4500m^3/h) towards the head of the animal.

Table 1

Protocol of treadmill exercise

Period	Duration	Gait (speed)	Inclination of treadmill (%)
I (warm up)	18 min	walking (1.8 m/sec)	0
II, III (exercise)	36 min	9 intervals of 3 min trotting (4.5 m/sec) followed by 1 min walking (1.8 m/sec)	0–9
IV, V (recovery)	36 min	walking (1.8 m/sec)	0
VI (recovery)	18 min	resting	0

Ridden exercise

The ridden exercise (Table 2) was performed in an indoor riding arena and consisted of a warm up period (I), two periods of trotting and cantering (II and III) and three recovery periods (walking IV and V, resting VI). The ambient temperature and humidity in the arena varied from 5.3°C to 16.6°C and 59% to 77%, respectively.

Table 2

Protocol of ridden exercise

Period	Duration	Gait
I (warm up)	18 min	walking
II, III (exercise)	36 min	4x trotting (3 min) followed by walking (1 min) 5 x cantering (3 min) followed by walking (1 min)
IV, V (recovery)	36 min	walking
VI (recovery)	18 min	resting

2.3. Measurements

Heart rate and blood lactate

Heart rate was determined by two electrodes (Polar Horse Transmitter, Polar Europe, Fleurier, Switzerland) placed under the girth and the values transmitted telemetrically (HT-434-T-7 and HT-434-R-4, Polar Europe, Fleurier, Switzerland) at 1 min intervals to a portable computer (Software, Polar Equine 4.0, Polar Inc., Kempele, Finland) for further evaluation. Blood samples for measuring lactate concentrations (Lactate

Pro™ Test Strip, KDK, Kyoto, Japan) were obtained by jugular venipuncture immediately after period III of treadmill and ridden exercise. The detection range of the lactate test is 0.8–23.3 mmol/L.

Scrotal surface temperature

The scrotal surface temperature (SST) was measured using specific thermistors (NTC BetaTHERM Thermistor100K6A1W2, BetaTHERM Ireland Limited, Ballybrit, Ireland) in a polyurethane tube (CCP, Clinical Plastics Products SA, La-Chaux-de-Fonds, Switzerland) sealed with Biresin U 1419 (Global Tool Trading AG, Kriens, Switzerland) and showing a high accuracy with an interchangeability of ± 0.05°C. Prior to each exercise session, two thermistors were fixed with silicon spray (Medical Adhesive B, Ulrich AG, St. Gallen, Switzerland) to the most ventral part of the scrotum over the left and right testis (Fig. 2). SST was transmitted by telemetry at 1 min intervals to a portable computer for further assessment.

Fig. 2. Placement of the thermistors on the most ventral part of the scrotum over each testis.

2.4. Statistical analysis

Data were analyzed using StatView 5.0 software program (SAS Institute, Wangen, Switzerland). ANOVA with repeated measures was carried out to analyze the effects of exercise (treadmill/riding) and suspensory (with/without) on heart rate, blood lactate concentration and SST. Period means were compared with Bonferroni-Dunn post hoc test. Correlation between left and right SST was calculated and differences assessed by Fisher's r to z test. Values were considered statistically significant at P < 0.05.

3. Results

3.1. Heart rate

The changes in mean heart rate during the six periods of treadmill and ridden exercise with and without suspensory are shown in Fig. 3. During the warm up period (I) mean heart rates fluctuated between 70 and 96 beats per min (bpm) during treadmill and between 61 and 74 bpm during ridden exercise. In periods II and III mean heart rates continuously increased to peak values of about 150 bpm in both exercise programs. At the beginning of recovery (IV) mean heart rates drastically dropped within 2 min to about 100 bpm, and then more slowly to values below 80 bpm at the end of recovery walking (V). Thereafter, another drop occurred and mean heart rates ranged between 40 and 50 bpm during the resting period VI. Comparing mean heart rate values between treadmill and ridden exercise with and without suspensory, no significant (P > 0.05) differences were obvious in any of the six periods.

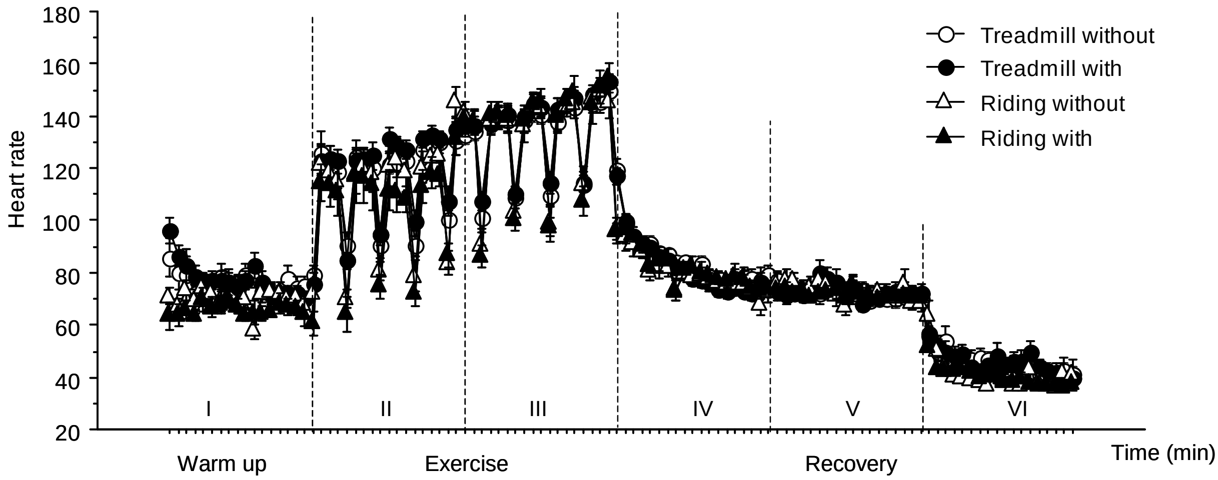

Fig. 3. Mean (±S.E.M.) of heart rate during periods I-VI (18 min each) of treadmill and ridden exercise, with and without suspensory in 12 stallions.

3.2. Blood lactate

Blood lactate concentrations measured immediately after exercise period III are shown in Fig. 4. The median values ranged between 1.1 and 1.3 mmol/L blood with no significant ($P > 0.05$) differences between treadmill and ridden exercise with and without suspensory. Normal resting values of blood lactate in horses are < 0.8 mmol/L.

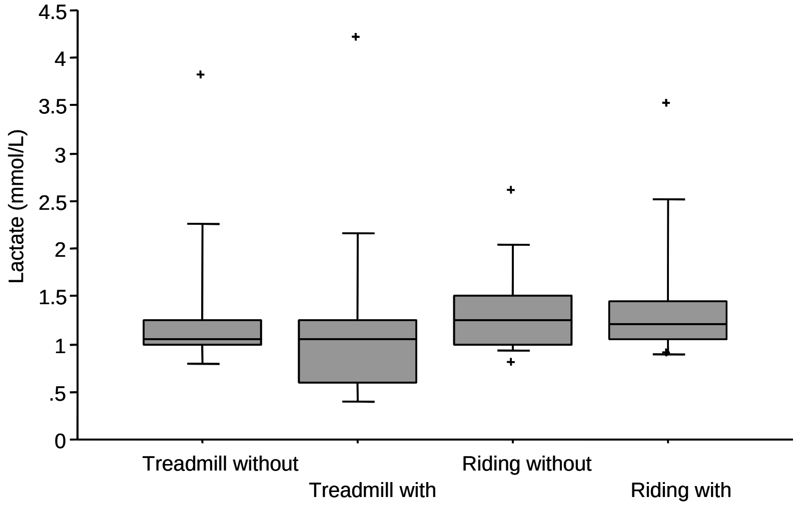

Fig. 4. Box plot of blood lactate concentrations after treadmill and ridden exercise, with and without suspensory in 12 stallions.

3.3. Scrotal surface temperature (SST)

SST values measured on the left and right scrotum were highly correlated (r = 0.79) and the means were not significantly different ($P > 0.05$). Therefore the average of both values was used for further analysis. In general, mean SST values were significantly ($P < 0.05$) influenced by type of exercise (treadmill/ridden) and by the wearing of a suspensory. The changes in mean SST during treadmill and ridden exercise are shown in Fig. 5. During treadmill exercise (Fig. 5a) a clear increase in mean SST was observed in period I, the peak values being significantly ($P < 0.05$) higher in stallions with (33.2±0.2°C) than in stallions without suspensory (32.1±0.2°C). When trotting was started (II) a rapid fall of SST was observed followed by a slight increase towards the end of period III, in stallions both with and without suspensory. During recovery (IV to VI), different temperature curves were observed between stallions with and without suspensory. In stallions without suspensory, mean SST slightly increased during walking recovery (IV und V) from 32.1±0.3°C to 32.4±0.3°C followed by a strong increase during resting recovery to peak values of 33.1± 0.2°C at the end of period VI. In stallions with suspensory mean SST initially decreased from 32.8±0.2°C to 31.7±0.2°C in period IV and then continuously increased to 33.8±0.2°C during periods V and VI.

Compared with treadmill exercise a different SST pattern was obtained during ridden exercise (Fig. 5b). In period I there was only a minor increase in SST from 31.1±0.2°C to 31.6±0.2°C in stallions with suspensory, whereas in stallions without suspensory SST dropped from 29.7±0.3°C to 29.1±0.3°C. During exercise periods II and III regular episodic changes in mean SST were observed fluctuating between 29.1±0.3°C and 27.1°C±0.3°C in stallions without and between 31.6±0.2°C and 29.1±0.3°C in stallions with suspensory. Mean SST was related to changes in gaits, decreasing during intervals of trotting and cantering followed by an increase during intervals of walking.

At the beginning of recovery (IV) mean SST rapidly rose from 27.1±0.3°C to 30.6± 0.2°C in stallions without and from 29.1±0.3°C to 32.5±0.2°C in stallions with suspensory. Thereafter, a parallel slow decline of SST was seen in both groups, with mean values dropping to 30.1±0.2°C in stallions without and to 31.7±0.2°C in those with suspensory at the end of period V. During period VI mean SST increased again to maximum values of 31.4±0.2°C without and 33.3±0.3°C with suspensory.

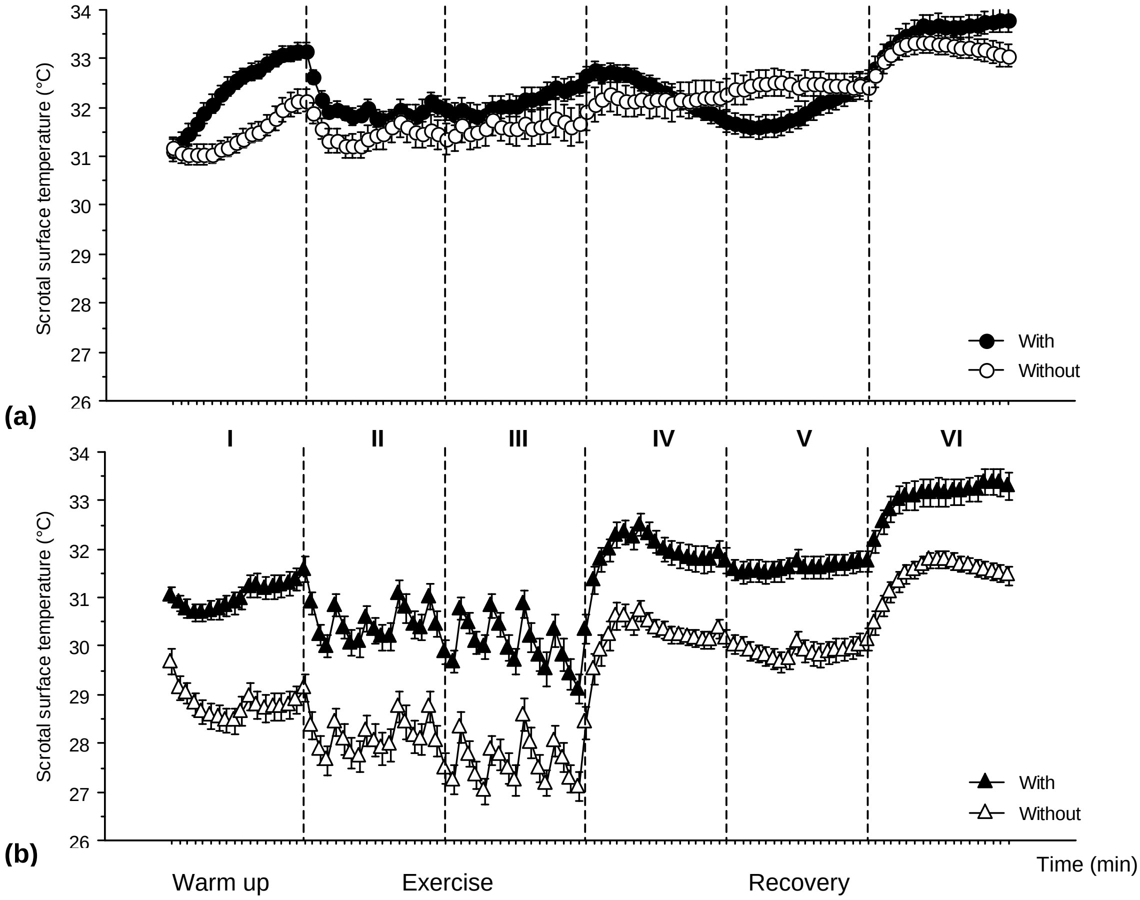

Fig. 5. Mean (±S.E.M.) of scrotal surface temperature during periods I-VI (18 min each) of treadmill (a) and ridden exercise (b), with and without suspensory in 12 stallions.

4. Discussion

Results of our investigation demonstrate for the first time that both exercise and the wearing of a suspensory have a significant influence on scrotal surface temperature. The intensity of exercise was reliably monitored during the experiment by heart rate and blood lactate concentrations. The evaluation of this data showed highly comparable values of heart rate and blood lactate concentrations, proving that the different types of exercise on the treadmill (walk and trot) and when ridden (walk, trot and canter) resulted in a very similar workload.

During treadmill and ridden exercise mean SST were generally higher in stallions with than without suspensory. The only exception was during walking recovery (periods IV and V) after treadmill exercise when mean SST in stallions with suspensory were lower than in stallions without suspensory. This difference in SST during recovery could be due to the amount of foamy sweat on the scrotal surface. This was increased in stallions wearing the netlike suspensory during treadmill exercise and might be responsible for the increased heat loss from the scrotal surface. When the stallions were at rest (period VI) SST first increased in all stallions, independently of the foregoing exercise, but after 10 min it started to decline in stallions without suspensory. This effect is assumed to be caused by relaxation of M. cremaster and Tunica dartos resulting in a larger scrotal surface, thus allowing a more rapid heat loss. The suspensory prevents this effect, keeping SST elevated.

During treadmill exercise, mean SST were consistently about 2°C higher and the differences between stallions with and without suspensory were smaller than during ridden exercise. These differences in SST seem most likely to be caused by increased air flow and lower ambient temperature in the riding arena. In the bull, ambient temperature has also been shown to have a clear effect on SST [24]. In contrast to treadmill exercise where SST continuously increased during periods II and III a completely different pattern was observed in all stallions during ridden exercise: Mean SST decreased during the 3 min trotting or cantering intervals followed by an immediate increase during walking. The faster the horse moved (i.e. during cantering) the greater was the cooling effect, as shown by the lower values during cantering with and without suspensory (29.1±0.3°C and 27.1±0.3°C) than during trotting (30.4°±0.3°C and 28.1°C±0.3°C). From these results we may conclude that the extent of airflow near the scrotum plays an important role in convection, which represents the transfer of heat between two media, such as the scrotal surface and the surrounding air. The effectiveness of convection is influenced by ambient temperature [25,26] and depends on how rapidly warm air is replaced by cooler air, i.e on the airflow. Thus, heat loss from the scrotal surface is maximized when the stallion is moving fast and / or with a high headwind.

In our study mean maximum SST was around 31°C before treadmill exercise and increased to peak values of about 33.5°C at the end of exercise. In an earlier study [27] using the same treadmill exercise protocol twice a week during one month, we were able to demonstrate a negative influence on semen quality. It is debatable whether the difference in SST of around 2.5°C observed in the present study is sufficient to damage spermatogenic cells. In the ram [28] it could be demonstrated that an intermittent, slight, but repeated increase in subcutaneous scrotal temperature of 1.4–2.0°C induced a significant decrease in fertility by increasing the embryonic mortality rate. A further study [29] showed that changes in SST are quickly transferred to superficial testicular veins of the testis which then, by heat exchange in the pampiniform plexus, alter the temperature of testicular arterial flow. In addition to elevated testicular temperature, other factors such as stress hormones (e.g. cortisol, endorphins, catecholamines) and stress related substances (e.g. lactate) must also be considered as having adverse effects on sperm production.

In conclusion, treadmill and ridden exercise significantly influenced SST. In stallions with suspensory the mean SST level was higher than without and therefore we recommend removing the suspensory immediately after exercise to prevent thermal testicular damage.

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